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TITLE: METHOD AND SYSTEM FOR  
PEER TO PEER COMMUNICATION  
IN A NETWORK ENVIRONMENT

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## METHOD AND SYSTEM FOR PEER TO PEER COMMUNICATION IN A NETWORK ENVIRONMENT

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### BACKGROUND OF THE INVENTION

### FIELD OF THE INVENTION

10 The present invention relates to methods for communicating between two or more "peer" target devices in a network environment. More specifically, the present invention relates to a method for communicating and distributing information, such as files or search commands, in a network environment by establishing first contact from a first peer target device to a predetermined  
15 number of neighbor nodes and receiving aggregated information, such as responses to commands and queries, about the network from the neighbor nodes.

### DESCRIPTION OF THE RELATED ART

20 During current approaches to distributing information, such as files or search commands, to one or more target devices in a network environment, one or more central servers may be used to communicate the information to a plurality of target devices.

Such a centralized system presents some difficulties. For example, an  
25 adverse effect on the central server will affect all target devices communicating with the server.

Other approaches to distributing information use a "peer-to-peer" means of distribution, i.e., a system in which two or more target devices are able to communicate directly with each other. Current protocols of "peer-to-peer"  
30 distributed searching and file-sharing present certain difficulties, however.

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For example, with the Napster "peer-to-peer" protocol, the files to be shared stay on each target device without passing through a server. However, Napster still uses a server to provide the ability to search for particular files and initiate a direct transfer between the clients. Thus, the Napster protocol may encounter some of the server-related difficulties described above. Additionally, the Napster protocol may encounter such peer-to-peer protocol-related problems as network congestion and search results that are constantly changing as target devices enter and leave the network. The Napster protocol may require large bandwidths, may slow communication and may impede results.

Meanwhile, with the Gnutella protocol, the files to be shared stay on each target device. Additionally, the capability to search for particular files and is also available on each target device. Thus, each target device is able to act as both client and server. However, when a search is conducted from an originating target device using the Gnutella protocol, the search results received at the originating target device may change from second to second as other target devices responding to the originating target device enter and leave the network. Furthermore, when a target device has a response to the originating target device, the results are relayed to the originating target device through the intervening target devices that forwarded the original request. As a search spreads over the Gnutella network, the path from the originating target device to another target device with the desired file may become longer and more convoluted. Thus, the search results may be delayed and may even become outdated before they arrive at the originating target device. The transfer of search results from target devices far away from the originating device may require large bandwidths, may slow communication and may impede results.

It would be desirable, therefore, to provide a method of communicating information among a plurality of target devices that is more efficient, reduces network and processor overhead and improves performance.

## SUMMARY OF THE INVENTION

One aspect of the present invention provides a method for communicating among a plurality of peer nodes in a network environment. A discovery command is communicated from a current peer node to at least one neighbor peer node, the neighbor peer node in communication with the current peer node. An aggregated list of peer nodes is received at the current peer node, the aggregated list of peer nodes comprising information about at least one peer node in communication with the at least one neighbor node.

The discovery command may be communicated from the current peer node after a predetermined delay has elapsed. The discovery command may be communicated to a predetermined number of neighbor peer nodes. A peer table may be created at the current peer node and updated with the aggregated list of peer nodes. A second discovery command from an originating peer node may be received at the current peer node and the peer table may be communicated to the originating peer node in response to the second discovery command. A data message having a unique descriptor may be received at the current peer node, the data message having a unique descriptor. The descriptor may be compared to a descriptor table, the descriptor table comprising a plurality of data messages and associated descriptors. The descriptor table may be updated with the received data message and the descriptor of the received data message. A query command may be forwarded from the current peer node to a predetermined number of neighbor peer nodes. Response data may be received directly at the current peer node from at least one other peer node, the at least one other peer node in communication with the at least one neighbor node. A query command from an originating peer node may be received at the current peer node and response data may be communicated directly from the current peer node to the originating peer node, in response to the query command. The query command may be forwarded from the current peer node to a predetermined number of neighbor peer nodes.

Another aspect of the present invention provides computer program product in a computer usable medium for communicating among a plurality of peer nodes in a network environment. The program may include means for communicating a discovery command from a current peer node to at least one neighbor peer node, the neighbor peer node in communication with the current peer node and means for receiving, at the current peer node, an aggregated list of peer nodes, the aggregated list of peer nodes comprising information about at least one peer node in communication with the at least one neighbor node.

Yet another aspect of the present invention provides a system for communicating among a plurality of peer nodes in a network environment. The system may include means for communicating a discovery command from a current peer node to at least one neighbor peer node, the neighbor peer node in communication with the current peer node and means for receiving, at the current peer node, an aggregated list of peer nodes, the aggregated list of peer nodes comprising information about at least one peer node in communication with the at least one neighbor node.

In one embodiment of the invention the program and system of the present invention may further include means for communicating the discovery command from the current peer node after a predetermined delay has elapsed. Means for communicating the discovery command to a predetermined number of neighbor peer nodes may be provided in accordance with the present invention, as well as means for creating a peer table at the current peer node and means for updating the peer table with the aggregated list of peer nodes. In addition, the program and system of the present invention may also comprise means for receiving, at the current peer node, a second discovery command from an originating peer node and means for communicating, from the current peer node directly to the originating peer node, the peer table in response to the second discovery command and for receiving a data message at the current peer node, the data message having a unique descriptor and means for comparing the descriptor of the received data message to a descriptor table, the descriptor

table comprising a plurality of data messages and associated descriptors.

Means for updating the descriptor table with the received data message and the descriptor of the received data message may be provided in accordance with the present invention. The program and system of the present invention may

- 5 include means for communicating a query command from the current peer node to a predetermined number of neighbor peer nodes. Additionally the program and system may comprise means for receiving, at the current peer node, response data directly from at least one other peer node, the at least one other peer node in communication with the at least one neighbor node as well as
- 10 means for receiving, at the current peer node, a query command from an originating peer node and means for communicating, from the current peer node directly to the originating peer node, response data in response to the query command. Means for forwarding the query command from the current peer node to a predetermined number of neighbor peer nodes may also be provided in
- 15 accordance with the program and system of the present invention.

The foregoing, and other, features and advantages of the invention will become further apparent from the following detailed description of the presently preferred embodiments, read in conjunction with the accompanying drawings.

- The detailed description and drawings are merely illustrative of the invention
- 20 rather than limiting, the scope of the invention being defined by the appended claims in equivalence thereof.

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## BRIEF DESCRIPTION OF THE DRAWINGS

**FIG. 1** is a schematic diagram of one embodiment of a network of data processing systems in accordance with the present invention;

5       **FIG. 2** is a block diagram of one embodiment of a data processing system in accordance with the present invention;

**FIG. 3** is a block diagram of another embodiment of a data processing system in accordance with the present invention;

10       **FIG. 4** is a flow diagram of one embodiment of a method of communicating among a plurality of target devices in a network environment in accordance with the present invention;

**FIG. 5** is a flow diagram of one embodiment of a subroutine in the method of communicating among a plurality of target devices in a network environment shown in **FIG. 4**;

15       **FIG. 6** is a flow diagram of one embodiment of another subroutine in the method of communicating among a plurality of target devices in a network environment shown in **FIG. 4**;

20       **FIG. 7** is a flow diagram of one embodiment of another subroutine in the method of communicating among a plurality of target devices in a network environment shown in **FIG. 4**; and

**FIG. 8** is a flow diagram of one embodiment of another subroutine in the method of communicating among a plurality of target devices in a network environment shown in **FIG. 4**.

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## DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

**FIG. 1** is a schematic representation of a network of data processing systems in accordance with the present invention at **100**. Network data processing system **100** may be a network of computers in which the present invention may be implemented. Network data processing system **100** may contain a network. Network **102** may be any suitable medium used to provide communications links between various devices, such as computers, connected to or in communication with each other within network data processing system **100**. For example, network **102** may include connections, such as wire connections, wireless communication links or fiber optic cables.

In the embodiment shown in **FIG. 1**, target devices **112, 114, 116, 118, 122, 124, 126, 128, 136, 138** may be in communication with network **102**. These target devices may be, for example, personal computers or network computers. One or more of target devices **112, 114, 116, 118, 122, 124, 126, 128, 136, 138** may serve as peer target devices as described further below. Target devices **112, 114, 116, 118, 122, 124, 126, 128, 136, 138** may also serve as peer nodes to one or more peer target devices as described further below. Network data processing system **100** may include additional servers, clients, target devices, and other devices not shown.

One or more storage units, such as storage unit **103, 105** may also be in communication with network **102**. Storage unit **103, 105** may store data, such as boot files, operating system images, application files and applications that may be processed or conveyed by one or more target devices **112, 114, 116, 118, 122, 124, 126, 128, 136, 138**. Storage unit **103, 105** may also store data to be made available to or processed by network **102** and/or to other components in communication with network **102** as described below. In some embodiments of the invention, storage units **103, 105** may also serve as peers to target devices **112, 114, 116, 118, 122, 124, 126, 128, 136, 138**, providing descriptors, messages and/or response data as detailed further below.



As seen in **FIG. 1**, network data processing system **100** may be any suitable system of processing data. For example system **100** may be the Internet. Alternatively, network data processing system **100** may also be any suitable type of network such as, for example, an intranet, a local area network (LAN) or a wide area network (WAN). In one embodiment of the invention, network **102** represents a worldwide collection of networks and gateways that use the TCP/IP suite of protocols to communicate with one another. A backbone of high-speed data communication lines between major nodes or host computers allows communication between thousands of commercial, government, educational and other computer systems that route data and messages.

In one embodiment of the invention, network data processing system is a peer-to-peer decentralized system. In such a system **100**, each one of target devices **112, 114, 116, 118, 122, 124, 126, 128, 136, 138** may serve as a server and may also serve as a client. Thus, target devices **112, 114, 116, 118, 122, 124, 126, 128, 136, 138** are able to perform tasks normally associated with clients and also to perform tasks normally associated with servers. In some embodiments of the invention, target devices **112, 114, 116, 118, 122, 124, 126, 128, 136, 138** may provide client-side interfaces through which users can perform client-related tasks, such as issuing queries and viewing search results. At the same time, each of target devices **112, 114, 116, 118, 122, 124, 126, 128, 136, 138** may also provide server-related tasks, such as accepting queries from other target devices, checking for requested data matches against its own data set and responding to other target devices with query results. Distributed system **100** is highly fault tolerant, as operation of system **100** will not be interrupted if a subset or node of target devices goes offline. For example, area **117** highlights one subset of target devices (comprising target devices **112, 114, 116, 118, 128, 136, 138**) of system **100**. Meanwhile, area **127** indicates a second subset of target devices (comprising target devices **122, 124, 126**) of system **100**. In a distributed system **100**, if the subset of area **117** goes offline, this will not necessarily interrupt the operation of system **100**, the operation of

network **102** or the operation of area **127** or target devices **122, 124, 126**.

Conversely, if the subset of area **127** goes offline, this will not necessarily interrupt the operation of system **100**, the operation of network **102** or the operation of area **117** or target devices **112, 114, 116, 118, 128, 136, 138**.

5           **FIGS. 2 and 3** are block diagrams of embodiments of data processing systems that may be used in accordance with the present invention. In one embodiment of the invention, a given target device **112, 114, 116, 118, 122, 124, 126, 128, 136, 138** may be a data processing system incorporating any combination of one or more of the components described in **FIGS. 2 and 3**.

10           **FIG. 2** is a block diagram of a data processing system in accordance with the present invention at **200**. In one embodiment of the invention, data processing system **200** may be implemented as one or more of the target devices **112, 114, 116, 118, 122, 124, 126, 128, 136, 138** shown in **FIG. 1**. Alternatively, a given target device **112, 114, 116, 118, 122, 124, 126, 128, 136,**  
15   **138** may incorporate one or more of the components described in **FIG. 2**.

          Data processing system **200** may be a symmetric multiprocessors (SMP) system including a plurality of processors **202** and **204** connected to system bus **206**. Alternatively, a single processor system may be employed. Memory controller/cache **208** may also be connected to system bus **206**. Memory  
20   controller/cache **208** may provide an interface to local memory **209**. I/O bus bridge **210** may also be connected to system bus **206** and may provide an interface to I/O bus **212**. Memory controller/cache **208** and I/O bus bridge **210** may be integrated as depicted or may be separate components.

          Peripheral component interconnect (PCI) bus bridge **214** connected to I/O  
25   bus **212** may provide an interface to PCI local bus **216**. One or more modems may be connected to PCI bus **216**. Typical PCI bus implementations will support four PCI expansion slots or add-in connectors. Modem **218** and network **220** may be connected to PCI local bus **216**. This connection may be through add-in boards. In one embodiment of the invention, modem **218** and accompanying

connections provide communications links to target devices such as network computers. For example, such target devices may be those described above at **FIG. 1**.

Additional PCI bus bridges **222** and **224** may provide interfaces for  
5 additional PCI buses **226** and **228**. Additional modems or network adapters may be supported from PCI buses **226** and **228**. For example, in one embodiment of the invention, PCI buses **226**, **228** may support a network adapter with a remote loading feature, such as the RPL feature, installed. In this manner, data processing system **200** may allow connections to multiple network computers. A  
10 memory-mapped graphics adapter **230** and hard disk **232** may also be connected to I/O bus **212** as depicted, either directly or indirectly.

The components depicted in **FIG. 2** may be arranged as shown or in any suitable manner that allows data processing system **200** to function as desired. Additionally, other peripheral devices, such as optical disk drives and the like,  
15 may be used in addition to or in place of the components depicted.

In one embodiment of the invention, data processing system **200** may include software and hardware components that enable system **200** to act according to a distributed peer-to-peer protocol in accordance with the present invention. This may include, for example, a set of data messages used for  
20 communicating data between one or more target devices and a set of rules governing the exchange of messages between one or more target devices. These messages and rules and methods of using these messages and rules in accordance with the present invention are further defined below.

**FIG. 3** is a block diagram of a data processing system in accordance with  
25 the present invention at **300**. In one embodiment of the invention, data processing system **300** may be implemented as one or more of the target devices **112**, **114**, **116**, **118**, **122**, **124**, **126**, **128**, **136**, **138** shown in **FIG. 1**. Alternatively, a given target device **112**, **114**, **116**, **118**, **122**, **124**, **126**, **128**, **136**, **138** may incorporate one or more of the components described in **FIG. 3**.

In one embodiment of the invention, data processing system **300** is a target device on which the disk drives are optional. Alternatively, data processing system **300** may be a stand-alone system configured to be bootable without relying on a network communication interface. Alternatively, data processing system **300** may also comprise one or more network communication interfaces. Data processing system **300** may also be a personal digital assistant (PDA) device. Data processing system may also take the form of a notebook computer or handheld computer. Alternatively, data processing system **300** may be a kiosk or Web appliance. The processes of the present invention may also be applied to a multiprocessor data processing system.

Data processing system **300** may employ a peripheral component interconnect (PCI) local bus architecture. Although the depicted example employs a PCI bus, other bus architectures such as Accelerated Graphics Port (AGP) and Industry Standard Architecture (ISA) may be used. Processor **302** and main memory **304** may be connected to PCI local bus **306** via PCI bridge **308**. PCI bridge **308** may also include an integrated memory controller and cache memory for processor **302**. Additional connections to PCI local bus **306** may be made through direct component interconnection or through add-in boards. In one embodiment of the invention, local area network (LAN) adapter **310**, SCSI host bus adapter **312**, and expansion bus interface **314** are connected to PCI local bus **306** by direct component connection. In contrast, audio adapter **316**, graphics adapter **318** and audio/video adapter **319** are connected to PCI local bus **306** by add-in boards inserted into expansion slots. Expansion bus interface **314** may provide a connection for additional components such as, for example, a keyboard and mouse adapter **320**, a modem **322** and additional memory **324**. A small computer system interface (SCSI) host bus adapter **312** may provide a connection for additional components such as, for example, a hard disk drive **326**, a tape drive **328**, a CD-ROM drive **330** or a DVD **332**. PCI local bus **306** may be any suitable local bus implementation. Typical PCI local bus implementations support three or four

PCI expansion slots or add-in connectors.

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Files and instructions for files such as operating files for an operating system, the object-oriented operating system, and applications or programs may be located on storage devices such as, for example, hard disk drive **326**. These operating systems, applications and/or programs may be loaded into main  
5 memory **304** for execution by processor **302**.

The components of system **300** depicted in **FIG. 3** may be arranged as shown or in any suitable manner that allows data processing system **300** to function as desired. Other internal hardware or peripheral devices, such as flash ROM (or equivalent nonvolatile memory) or optical disk drives and the like,  
10 may be used in addition to or in place of the components depicted. For example, one embodiment of data processing system **300** may be configured with ROM and/or flash ROM in order to provide non-volatile memory for storing operating system files and/or user-generated data. Another embodiment of data processing system **300** may include network adapters suited to transmit or  
15 receive functions of a remote loading program and/or feature such as the RPL feature.

In one embodiment of the invention, data processing system **300** may include software and hardware components that enable system **300** to act according to a distributed peer-to-peer protocol in accordance with the present  
20 invention. This may include, for example, a set of data messages used for communicating data between one or more target devices and a set of rules governing the exchange of messages between one or more target devices. These messages and rules and methods of using these messages and rules in accordance with the present invention are further defined below.

25 **FIG. 4** shows one embodiment of a method for communicating among a plurality of target devices in accordance with the present invention at **400**. The method shown in **FIG. 4** may be implemented using any suitable peer-to-peer protocol that enables distributed searching and file sharing over networks.

Any suitable transport mechanism may be used to accomplish communication between the target devices or nodes, for example, using HTTP over TCP. Alternatively, a byte-level transport may be used. Alternatively, UDP  
5 may be used. Alternatively, HTTP/SOAP (Simple Object Access Protocol) may be used. SOAP is a simple XML-over-HTTP wrapper for popular connective technologies, such as COM, Apple Events and CORBA. The transport mechanism for SOAP is HTTP and a call in SOAP is specified using XML.

In one embodiment of the invention, the transport mechanism  
10 accomplishes communication between target devices in accordance with a suitable peer-to-peer protocol. This peer-to-peer protocol may include, for example, a set of data messages used for communicating data between one or more target devices and a set of rules governing the exchange of messages between one or more target devices. These messages and rules and methods  
15 of using these messages and rules in accordance with the present invention are further defined below.

For example, in one embodiment of the invention, one or more data messages may be sent between one or more target devices. These data messages may include any suitable data, such as responses to queries or  
20 commands, to be communicated from one target device to another. These data messages may be, for example, information in the form of 8-byte strings, 16-byte strings, 32-byte strings or any suitable sized string of data. The data messages may take the form of, for example, discovery (denoted herein as "ping") data messages, identification (denoted herein as "pong") data messages, query data  
25 messages and query response data messages. The data messages may be governed, for example, by rules such as timeout delays and time to live counters, as are well known in the art.

In accordance with the present invention, the data message may include a descriptor ID. In one embodiment of the invention, the descriptor ID may be a 16-byte string uniquely identifying a particular data message that is distributed on network **102** and/or system **100**. For example, a 32-byte string sized data message may include a 16-byte string sized descriptor ID that uniquely distinguishes it from every other data message sent over the network. Thus, if a message comes to a particular target device more than once, the target device is able to recognize the message from the descriptor ID of the message.

As indicated above, the data message may be a discovery message (denoted herein as a "ping" message). This ping message may be used by one or more target devices **112, 114, 116, 118, 112, 124, 126, 128, 136, 138** to indicate that the ping message is actively querying network **102** and/or system **100**. Such a ping data message may request the identification of one or more target devices. For example, target device **114** may send out a ping message to target devices **112, 116** and **118** asking target devices **112, 116, 118** to identify themselves. In one embodiment of the invention, a ping data message may request that the identification include an aggregated list (peer table) of a given target device's peer target devices. For example, target device **114** may send out a ping message to target devices **112, 116, 118** asking target device **112** to identify target device **112**'s peer devices, asking target device **116** to identify target device **116**'s peer devices and asking target device **118** to identify target device **118**'s peer devices.

In one embodiment of the invention, the peer-to-peer protocol may also include a ping timeout delay, which may be one rule used to govern ping data messages. This ping timeout delay may be a predetermined amount of time before a particular ping is sent out. For example, a ping may be sent out from a particular target device every  $p$  seconds. The value of the ping timeout delay may be determined using any suitable means known in the art. For example, the ping timeout value may be preset based on the specifications of the target



device controlling the ping timeout delay. Alternatively, the user of a particular target device may set the value of the ping timeout delay. Alternatively, the ping timeout delay value may be based on such factors as network congestion and processing speed of the target device. Alternatively, the transport mechanism  
5 used by a given target device may determine the ping timeout delay value. Alternatively, a suitable algorithm may govern the ping timeout delay value. This algorithm may be based on, for example, the system limitations of a particular target device (peer node) or may be based on user input values.

As described above, the data message may also be an identification  
10 message (denoted herein as a pong data message). This pong message may be used by one or more target devices **112, 114, 116, 118, 112, 124, 126, 128, 136, 138** to respond to a target device that has broadcast a ping message. For example, target device **112** may send a pong message to target device **114** describing target device **112** to target device **114**. In one embodiment of the  
15 invention, the pong message may contain the address of an active target device. Thus, target device **112** may send a pong message to target device **114** that gives the address of target device **112**. If target device **114** has also sent a ping message to target device **118**, target device **114** may also receive a pong message from target device **118**, giving the IP address of target device **118**.  
20 Alternatively, a pong data message may include one or more of the following: a port number on which the responding target device can accept incoming connections, the IP address of the responding target device, the number of files that the responding target device is sharing on the network, the number of  
25 kilobytes of data that the responding target device is sharing on the network. In one embodiment of the invention the pong data message may provide an aggregated list (or peer table) of the neighbor peer devices of a given target device. For example, target device **112** may send a pong message to target device **114** indicating to target device **114** that target device **112** has only 1  
30 peer—target device **114**. Meanwhile, target device **118** may also send a pong message to target device **114** indicating to target device **114** that target device

118 has 3 peers—target devices **114, 128, 138**. The pong message from target device **118** may also provide information about the three peer devices **114, 128, 138** of target device **118**, including the port number on which peer target device **114** can accept incoming connections, the port number on which second peer target device **128** can accept incoming connections, the port number on which third peer target device **138** can accept incoming connections, the IP address of peer target device **114**, the IP address of second peer target device **128**, the IP address of third peer target device **128** and any other suitable information.

As described above, the data message may also be a query message.

10 This query message may be used by one or more target devices **112, 114, 116, 118, 112, 124, 126, 128, 136, 138** to request information from other target devices and any other components of network **102** or system **100**. The query message may request, for example, information about software or hardware components of a given target device, about software or hardware configurations of a given target device, about software or hardware compatibility of a given target device or about files in the memory of a given target device. For example, target device **114** may send out a query data message to target devices **112, 116, 118** asking target devices **112, 116, 118** if they have a particular file. In one embodiment of the invention, the query message may also include a request for an aggregated list (or peer table) of its peer target devices. Other types of queries may also be broadcast in accordance with the present invention as is known in the art.

As described above, the data message may also be a response data message. This pong message may be used by one or more target devices **112, 114, 116, 118, 112, 124, 126, 128, 136, 138** to respond to a target device that has broadcast a query message. For example, target device **112** may send a response message to target device **114** indicating whether target device **112** has the file that target device **114** is seeking. If target device **114** has also sent a ping message to target device **118**, target device **114** may also receive a

response data message from target device **118** indicating whether target device **118** has the file that target device **114** is seeking.

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The peer-to-peer protocol may allow any one of target devices **112, 114, 116, 118, 112, 124, 126, 128, 136, 138** to broadcast or receive data messages. Thus, for example, target device **128** may also send a ping message to target device **118** requesting an aggregated list of target device **118**'s peer target devices. Therefore, target device **128** may also receive a pong from target device **118**, providing information about the three peer devices **114, 128, 138** of target device **118**, including the port number on which peer target device **114** can accept incoming connections, the port number on which second peer target device **128** can accept incoming connections, the port number on which third peer target device **138** can accept incoming connections, the IP address of peer target device **114**, the IP address of second peer target device **128**, the IP address of third peer target device **128** and any other suitable information. Meanwhile, target device **116** may broadcast a query message and receive response data messages from other target devices **112, 114, 118, 112, 124, 126, 128, 136, 138**.

Thus, the routine shown in **FIG. 4** may take place at any one of target devices **112, 114, 116, 118, 112, 124, 126, 128, 136, 138** and, in one embodiment of the invention, may be occurring simultaneously at more than one given target device. Additionally, any one or target devices may be receiving data messages, such as, for example, peer tables, resulting from the routine of **FIG. 4**. Therefore, although the following paragraphs designate target device **114** as the originating peer node in relation to network **102** and target devices **112, 116, 118, 112, 124, 126, 128, 136, 138**, any one or more of target devices **112, 116, 118, 112, 124, 126, 128, 136, 138** may also be originating peer nodes in relation to any other target devices in network **102** and/or system **100**.

As seen at block **402**, target device **114** may initialize a peer table. In one embodiment of the invention, this peer table may comprise a list of peer target devices and related information for each peer target device, such as IP

addresses of each peer target device and the port on which each particular peer target device is accepting incoming connections. This may be accomplished in any suitable manner, such as, for example, by creating a database on or in communication with target device **114** for storing identifications of peer target devices and related information. Alternatively, this information may be collated in a suitable storage location on or in communication with target device **114**. Alternatively, this information may be stored in a hash table and/or using a hashing function as is well known in the art.

As seen at block **404**, target device **114** may also initialize a descriptor ID table. In one embodiment of the invention, this descriptor ID table may comprise a list of each unique descriptor ID and its corresponding data message received by and/or transmitted by target device **114**. This may be accomplished in any suitable manner, such as, for example, by creating a database on or in communication with target device **114** for storing lists of descriptor IDs and related information. Alternatively, this information may be collated in a suitable storage location on or in communication with target device **114**. Alternatively, this information may be stored in a hash table and/or using a hashing function as is well known in the art.

As seen at block **406**, target device **114** may also set a value for a “ping” timeout delay as described above. This ping timeout delay may be a predetermined amount of time before a particular ping is sent out. For example, a ping may be sent out from a particular target device every  $p$  seconds. The value of the ping timeout delay may be determined using any suitable means known in the art. For example, the ping timeout value may be preset based on the specifications of the target device controlling the ping timeout delay. Alternatively, the user of a particular target device may set the value of the ping timeout delay. The ping timeout delay value may be based on such factors as network congestion and processing speed of the target device. The transport mechanism used by a given target device may determine the ping timeout delay value. A suitable algorithm may govern the ping timeout delay value. This

algorithm may be based on, for example, the system limitations of a particular target device (peer node) or may be based on user input values.

As seen at block 408, target device 114 may then set a value  $n$  for the number of neighbor nodes (peer target devices) it will contact, i.e., connect with.

- 5 The number of neighbor nodes to be contacted for a given target device may be determined using one or more suitable methods known in the art. For example, the number of peer nodes contacted from a given target device may be based on suitable parameters for the target device, such as, for example, user determined parameters, hardware parameters of the target device, software parameters of
- 10 the target device, etc. For example, the user of a given target device 114 may indicate that target device 114 should contact at least 3 other neighbor nodes. Alternatively, the processing limitations of target device 114 may dictate that it should contact no more than 4 peer target devices. Alternatively, target device 114 may be pre-set to communicate with a given number of neighbor nodes.
- 15 Alternatively, the transport mechanism used by a given target device may determine the number of neighbor nodes to be contacted. Alternatively, a suitable algorithm may govern the number of neighbor nodes to be contacted such as an algorithm based on number of neighbor nodes within network 102 or system 100 or based on user input values.

- 20 As seen at block 410, target device 114 may then set a time to live value  $t$  for the number of times a data message may be forwarded from one target device to another before the message expires. For example, target device 114 may set a data message to expire after it has been received by  $t$  number of target devices. The time to live value may be determined using any suitable
- 25 means. For example, the value may be preset based on the specifications of the target device controlling the time to live value. Alternatively, the user of a particular target device may set the time to live value. The time to live value may be based on such factors as network congestion and processing speed of the target device. The transport mechanism used by a given target device may
- 30 determine the time to live value. A suitable algorithm may govern the time to live

value based on such factors as network congestion and processing limitations of a given peer node.

Each target device receiving a data message with a time to live value may increment a hops counter associated with the data message. This hops counter may be incremented by the target device upon receipt of the message using any suitable means known in the art. For example, a suitable algorithm may be used to increment the hops counter. As with the time to live value, the algorithm for determining the hops counter may be based on factors such as network limitations and processing limitations of a given peer node. This hops counter may indicate the number of times the data message has been received and may be compared against the time to live value  $t$  to determine if the message should be expired (i.e., does the number of times the message has been received, or the hops count, exceed the time to live value?).

As seen at blocks **420**, **430** and **440**, originating peer node **114** may also conduct one or more of the following threads: a ping thread, a server thread and a query thread. These threads may be conducted by target device **114** simultaneously or in any suitable order. These threads may occur continuously while target device **114** is on-line or in communication with network **102** and/or system **100**. Alternatively, target device **114** may begin one or more of the threads upon receiving one or more data messages from another target device **112**, **116**, **118**, **122**, **124**, **126**, **128**, **136**, **138**, or from any other component of network **102** and/or system **100**.

As seen at block **420**, target device **114** may thus begin a "ping" thread, described further below. Alternatively or simultaneously with block **420**, target device **114** may also begin a "server" thread, described further below, as seen at block **430**. Alternatively or simultaneously with blocks **420**, **430**, target device **114** may also begin a "query" thread, described further below as seen at block **450**. Target device **114** may begin the "query" thread if it is determined at block **440** that one or more queries are to be broadcast from target device **114**. Thus, in accordance with the present invention, target device **114** may perform client

functions such as sending out queries, including ping queries and receiving responses, including pong responses. Target device **114** may also perform server functions such as processing queries and responses, including aggregating responses describing peer nodes into a peer table or tracking the  
5 times a particular query message is received.

**FIG. 5** shows one embodiment of a subroutine in the method of communicating among a plurality of target devices in a network environment of **FIG. 4** at **500**.

As seen at block **502**, target device **114** may wait for the duration of the  
10 predetermined ping timeout delay value ( $p$ ) determined at block **406**. This ping timeout delay may be a predetermined amount of time before a particular ping is sent out. For example, a ping may be sent out from a particular target device every  $p$  seconds.

As seen at block **504**, once the ping timeout delay value has elapsed,  
15 target device **114** may send a ping message to the predetermined number of neighbor (peer) nodes ( $n$ ) set at block **408**. Thus, in the embodiment shown in **FIG. 1**, the ping message is sent from target device **114** to three predetermined neighbor nodes **112**, **116**, **118** (i.e.,  $n = 3$ ).

This ping message may be used by one or more target devices **112**, **114**,  
20 **116**, **118**, **112**, **124**, **126**, **128**, **136**, **138** to indicate that the ping message is actively querying network **102** and/or system **100**. Such a ping data message may request the identification of one or more target devices. For example, target device **114** may send out a ping message to target devices **112**, **116** and **118** asking target devices **112**, **116**, **118** to identify themselves. In one  
25 embodiment of the invention, a ping data message may request that the identification include an aggregated list (peer table) of a given target device's peer target devices. For example, target device **114** may send out a ping message to target devices **112**, **116**, **118** asking target device **112** to identify target device **112**'s peer devices, asking target device **116** to identify target



device **116**'s peer devices and asking target device **118** to identify target device **118**'s peer devices.

As seen at block **506**, target device **114** may then receive pong messages from one or more of the predetermined number of peers contacted at block **504**.

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This pong message may be used by the contacted peer devices **112**, **116**, **118** to respond to the ping message broadcast by target device **114**. For example, target device **112** may send a pong message to target device **114** describing target device **112** to target device **114**. In one embodiment of the invention, the pong message may contain the address of an active target device. Thus, target device **112** may send a pong message to target device **114** that gives the address of target device **112**. Target device **114** may also receive a pong message from target device **116**, giving the IP address of target device **116**, and a pong message from target device **118**, giving the IP address of target device **118**. In one embodiment of the invention the pong data message may provide an aggregated list (or peer table) of the neighbor peer devices of a given target device. For example, target device **112** may send a pong message to target device **114** indicating to target device **114** that target device **112** has only 1 peer—target device **114**. Meanwhile target device **116** may also send a pong message indicating that target device **116** has two peers—target devices **114**, **136**. The pong message from target device **116** may also provide information about the two peer devices **114**, **136** of target device **116**, including the port number on which peer target device **114** can accept incoming connections, the port number on which second peer target device **136** can accept incoming connections, the IP address of peer target device **114**, the IP address of second peer target device **136** and any other suitable information. Furthermore, target device **118** may also send a pong message to target device **114** indicating to target device **114** that target device **118** has 3 peers—target devices **114**, **128**, **138**. The pong message from target device **118** may also provide information about the three peer devices **114**, **128**, **138** of target device **118**, including the port number on which peer target device **114** can accept incoming connections, the port number on which second peer target device **128** can accept incoming connections, the port number on which third peer target device **138** can accept

incoming connections, the IP address of peer target device **114**, the IP address of second peer target device **128**, the IP address of third peer target device **128** and any other suitable information.

As seen at block **508**, target device **114** may then update the peer table  
5 initialized at block **402** with information received from the pong responses. This may be accomplished using any suitable means known in the art such as entering the peer table information from neighbor peer nodes **112**, **116**, **118** into a database or a storage location that is on or in communication with target device **114**. Thus, from querying peer target devices **112**, **116**, **118**, target  
10 device **114** is able to determine information about other devices **128**, **138**, **136** in the network. Meanwhile, because target device **114** is able to update its peer table with information about target devices **112**, **116**, **136**, **118**, **128**, **138**, a neighbor device **122** querying target device **114** would subsequently receive information about seven target devices from target devices **114**—that is,  
15 information about target devices **112**, **116**, **136**, **118**, **128**, **138**, and **122**.

**FIG. 6** shows one embodiment of another subroutine in the method of communicating among a plurality of target devices in a network environment of **FIG. 4** at **600**.

As seen at block **602**, target device **114** may wait for an incoming data  
20 message. This data message may be any suitable data message as described above.

For example, the data message may be a ping data message requesting information from target device **114**, such as a data message requesting the identification of target device **114**. Alternatively, the data message may be a  
25 query data message asking target device **114** if it has a particular file. In one embodiment of the invention, the data message may be a request that target device **114** provide an aggregated list (or peer table) of its peer target devices.

Alternatively the data message may be a pong data message describing another target device to target device **114**. In one embodiment of the invention,  
30 the pong data message may also provide an aggregated list (or peer table) of its

neighbor peer devices. For example, target device **114** may receive a data message from target device **112** indicating to target device **114** that target device **112** has only 1 peer—target device **114**. Alternatively, the data message may be a response data message responding to a query from target device **114**.

5       At block **604**, target device **114** determines if it has received a data message. Each data message, whatever its nature (i.e., ping data message, pong data message, search query message, etc.) may have a unique descriptor ID as described above.

10       If a data message has been received, the method proceeds to block **606**, where the descriptor ID of the data message is compared to descriptor IDs of messages already stored in the Descriptor ID table created at block **404**.

At block **608**, target device **114** determines if the received data message has been seen before (i.e., if the received data message's descriptor ID matches any of the descriptor IDs already stored in the Descriptor ID table).

15       As seen at block **610**, if the received message has not been seen before, target device **114** may add the received message and its corresponding descriptor ID to the Descriptor ID table.

As seen at block **612**, target device **114** may then determine if the received message is a ping message as described above. If the received message is a message, as seen at block **624**, target device **114** may return a pong message to the peer node from which the received message originated. In one embodiment of the invention, the pong response from target device **114** may include one or more of the following: a port number on which target device **114** can accept incoming connections, the IP address of target device **114**, the number of files that the target device **114** is sharing on the network, the number of kilobytes of data that the target device **114** is sharing on the network. Alternatively, in one embodiment of the invention, the pong response from target device **114** may include all or part of an aggregated list (or peer table) of its neighbor peer devices. For example, in the embodiment of **FIG. 1**, the pong response from target device **114** may include information about target devices

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112, 116, 136, 118, 128, 138, such as port numbers on which target devices 112, 114, 116, 136, 118, 128, 138, can accept incoming connections, IP addresses of target devices 112, 116, 136, 118, 128, 138, and any other suitable information.

5 In accordance with the present invention, the pong response is transmitted directly from the receiving target device 114 to the originating peer target device rather than being forwarded from the receiving target device through intervening target devices. Thus, for example, in the embodiment of FIG. 1, if target device 114 receives a ping message from peer target device 128  
10 via intervening target device 118, target device 114 may respond directly to target device 128 with a pong message. Target device 114 may be enabled to respond directly to target device 128 because information about target device 128 has been made available to target device 114 in accordance with the present invention. For example, target device 114 may have information about  
15 target device 128 because target device 114 has previously updated its peer table with information about target device 128, such as the IP address of target device 128 (as seen at block 508).

Moreover, as seen at block 626, target device 114 may further update its peer table by adding information about the originating peer node to its peer  
20 table. Thus, continuing the above example, in the embodiment of FIG. 1, target device 114 may add information about target device 128 to its peer table. This information may include information about target device 128 such as the port number on which target device 128 can accept incoming connections, the IP address of target device 128, the number of files that the target device 128 is  
25 sharing on the network, the number of kilobytes of data that the target device 128 is sharing on the network. Alternatively, in one embodiment of the invention, the information from target device 128 may include all or part of an aggregated list (or peer table) of its neighbor peer devices. For example, in the embodiment of FIG. 1, the information from target device 128 may include

information about other target devices connected with or in communication with target device **128** (not shown).

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As seen at block **614**, if the received message is not a ping data message, target device **114** may determine if the received message is another type of query. The query message may request, for example, information about software or hardware components of a given target device, about software or hardware configurations of a given target device, about software or hardware compatibility of a given target device or about files in the memory of a given target device. In one embodiment of the invention, the query message may describe a predetermined set of criteria to be met by a given target device (e.g., "Does the target device receiving this message have a file called PATENT.APP.DOC?" or "Is the target device receiving this message capable of running DOS?") If the received message is another type of query, the method of the present invention may proceed to the subroutine illustrated in **FIG. 8**, as indicated at **D** in **FIG. 6**.

**FIG. 8** shows one embodiment of another subroutine in the method of communicating among a plurality of target devices in a network environment of **FIG. 4** at **800**.

As seen at block **802**, target device **114** may determine if it meets the predetermined criteria included in the query of the message received at block **604**. This may be accomplished for example, by comparing the criteria included in the query message with any suitable component of target device **114**. For example, if the received query message asks "Does the target device receiving this message have a file called PATENT.APP.DOC?", target device **114** may examine its files to determine if any files match the file requested in the received query message. If the received query message is asking "Is the target device receiving this message capable of running DOS?," target device **114** may evaluate its own system configuration to determine if it matches the configuration described in the received query message.

As seen at block **804**, if target device **114** does meet the predetermined criteria, target device **114** may return response data to the target device from which the query originated. For example, target device **112** may broadcast a query message asking "Does the target device receiving this message have a file named 'PATENT.APP.DOC?'" If target device **114** has the file PATENT.APP.DOC (i.e., meets the predetermined criteria), target device **114** may send a response to target device **112** indicating that target device **114** has the file. In one embodiment of the invention, if target device **114** does not have the file, target device **114** may also send a response indicating that it does not have the file.

In accordance with the present invention, if current target device **114** meets the predetermined criteria, target device **114** returns its response data directly to the originating peer target device rather than being forwarded from current target device **114** through intervening target devices. Thus, for example, in the embodiment of **FIG. 1**, if target device **114** receives a search query from peer target device **128** via intervening target device **118**, target device **114** will send its response data directly to target device **128**. Target device **114** may be enabled to respond directly to target device **128** because information about target device **128** has been made available to target device **114** in accordance with the present invention. For example, target device **114** may have information about target device **128** because target device **114** has previously updated its peer table with information about target device **128**, such as the IP address of target device **128** (as seen at block **508**).

Whether or not target device **114** meets the predetermined criteria of the query message, as seen at blocks **814**, **816**, **818**, **828**, the target device **114** may then determine whether to forward or expire the data message.



As seen at block **814**, the query message may include or be associated with a hops counter, which may be incremented upon receipt of the data message. This hops counter may be incremented by the receiving target device  
5 **114** using any suitable means known in the art. For example, a suitable algorithm may be used to increment the hops counter. The algorithm for determining the hops counter may be based on factors such as network limitations and processing limitations of a given peer node. The hops counter may indicate the number of times the data message has been received. In one  
10 embodiment of the invention, each target device receiving the data message increments the hops counter each time the data message is received.

As seen at block **816**, the hops counter may be compared against the time to live value  $t$  for the particular data message in order to determine if the message should be expired (i.e., does the number of times the message has  
15 been received, or the hops count, equal the time to live value?). In the embodiment shown in **FIG. 8**, the hops counter is compared against the time to live value  $t$  to determine if the hops counter is equal to the time to live value, and, if the hops counter is not equal, the message does not expire. In another embodiment of the invention, the hops counter is compared against the time to  
20 live value  $t$  to determine if the hops counter is greater than the time to live value, and, if the hops counter is greater than the time to live value, the message does not expire. In yet another embodiment of the invention, the hops counter is compared against the time to live value  $t$  to determine if the hops counter is less than the time to live value, and, if the hops counter is less than the time to live  
25 value, the message does not expire.

The time to live value may be determined using any suitable means. For example, the value may be preset based on the specifications of the target device controlling the time to live value. In one embodiment of the invention, the target device controlling the time to live value is the target device from which the  
30 data message originated. Alternatively, the user of a particular target device

may set the time to live value. The time to live value may be based on such factors as network congestion and processing speed of the target device. The transport mechanism used by a given target device may determine the time to live value. Alternatively, a suitable algorithm may govern the time to live value based on such factors as network congestion and processing limitations of a given peer node.

As seen at block **818**, if the hops counter equals the time to live value, the message may be expired. In one embodiment of the invention, once the message is expired, the receiving target device **114** no longer forwards the message to another target device.

As seen at block **828**, if the hops counter does not equal the time to live value, target device **114** may then proceed to forward the data message to one or more other target devices. In the embodiment shown in **FIG. 8**, for example, the receiving target device may forward the message to a predetermined number ( $n$ ) of neighbor nodes/peer target devices. This predetermined number of neighbor nodes may be determined by any suitable means, including those described at block **408** above.

Receiving target device **114** may then return to block **602**, as indicated at **B** in **FIGS. 6** and **8**.

Returning now to **FIG. 6**, if the received message is not a ping message or query message, as seen at block **616**, target device **114** may determine if the received message is a data message providing response data to a query broadcast by target device **114**.

Such response data may be, for example, one or more of the following:  
port numbers on which one or more neighboring target devices can accept  
incoming connections, IP addresses of one or more neighboring target devices,  
the number of files that one or more neighboring target devices are sharing on  
5 the network, the number of kilobytes of data that one or more neighboring target  
devices is sharing on the network, information about software or hardware  
components of a given target device or about one or more neighboring target  
devices, information about software or hardware configurations of a given target  
device or about one or more neighboring target devices, information about  
10 software or hardware compatibility of a given target device or about one or more  
neighboring target devices or information about files available to a given target  
device or files available to one or more neighboring target devices.

The response data may also include all or part of an aggregated list  
(or peer table) from one or more neighbor peer devices. Alternatively, the  
15 response data may include an answer to a query sent by target device 114. For  
example, if target device 114 broadcasts a query asking "Do you have a file  
named TRADEMARK.APP.EXE?", the received message may be a response  
indicating that one or more neighboring target devices have the file. In one  
embodiment of the invention, the response data may be sent directly from a  
20 responding target device to the target device originally broadcasting the query.

For example, in the embodiment of **FIG. 1**, if target device 114 sends a  
query to neighbor devices 112, 116, 118, target device 114 may receive a  
response data message from target device 112 indicating to target device 114  
whether target device 112 has the file. Target device 114 may also receive a  
25 data message from target device 116 indicating to target device 114 whether  
target device 116 has the file. Target device 114 may receive a data message  
from target device 118 indicating to target device 114 whether target device 118  
has the file.

In addition, target device **114** may receive a data message directly from target device **136** indicating to target device **114** whether target device **136** has the file, even though target device **114** did not query target device **136** directly. Target device **136** may be enabled to respond directly to target device **114** because information about target device **114** has been made available to target device **136** in accordance with the present invention. For example, target device **136** may have information about target device **114** because target device **136** has previously updated its peer table with information about target device **114**, such as the IP address of target device **114** (as seen at block **508**).

Target device **114** may also receive data messages directly from target devices **128**, **138** indicating whether each of these target devices **128**, **138** has the file, even though target device **114** did not query target devices **128**, **138** directly. Thus, from querying target devices **112**, **116**, **118**, target device **114** is able to receive direct responses from target devices **112**, **116**, **136**, **118**, **128**, **136**.

As seen at block **618**, target device **114** may then process the response data. For example, target device **114** may store the response data in a storage location on or in communication with target device **114**. Alternatively, target device **114** may present the response data to a user via a user interface on or in communication with target device **114**. For example, target device **114** may display the response data as search results to the user.

As indicated in **FIG. 6** by loop **630**, the routine of **FIG. 6** may be repeated for any and all incoming messages.

**FIG. 7** shows one embodiment of another subroutine in the method of communicating among a plurality of target devices in a network environment of **FIG. 4** at **700**.

As seen at block **702**, target device **114** may wait until a query is input. This query may be any suitable query as described above. The query may request information on, for example, one or more of the following: port numbers on which one or more neighboring target devices can accept incoming connections, IP addresses of one or more neighboring target devices, the number of files that one or more neighboring target devices are sharing on the network, the number of kilobytes of data that one or more neighboring target devices is sharing on the network, information about software or hardware components of a given target device or about one or more neighboring target devices, information about software or hardware configurations of a given target device or about one or more neighboring target devices, information about software or hardware compatibility of a given target device or about one or more neighboring target devices or information about files available to a given target device or files available to one or more neighboring target devices.

In one embodiment of the invention, a user may input a query. Alternatively, the query may be input from another target device or another component of network **102** and/or system **100**. For example, a user may input, at target device **114** a query asking for the file "PATENT.APP.DOC".

As seen at block **704**, target device **114** may then forward the query to a predetermined number of neighbor nodes  $n$ . This predetermined number of neighbor nodes may be determined by any suitable means, including those described at block **408** above. Target device **114** may then return to block **702**, as indicated at **C** in **FIGS. 4** and **7**.

While the present invention has been described in the context of a fully functioning data processing system, it will be appreciated that the processes described may be distributed in any other suitable context. For example, the processes described may take the form of a computer readable medium of instructions. The present invention applies equally regardless of the type of signal-bearing media actually used to carry out the distribution. Examples of computer readable media include recordable-type media, such as a floppy disk, a hard disk drive, a RAM, CD-ROMs, DVD-ROMS, and transmission-type media, such as digital and analog communications links, wired or wireless communications links using transmission forms such as, for example, radio frequency and light wave transmissions. The computer readable media may take the form of coded formats that are decoded for actual use in a particular data processing system.

It will be appreciated by those skilled in the art that while the invention has been described above in connection with particular embodiments and examples, the invention is not necessarily so limited, and that numerous other embodiments, examples, uses, modifications and departures from the embodiments, examples and uses are intended to be encompassed by the claims attached hereto. The entire disclosure of each patent and publication cited herein is incorporated by reference, as if each such patent or publication were individually incorporated by reference herein.